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SHORT COMMUNICATION

Measurement validity of an electronic inspiratory loading device during a loaded breathing task in patients with COPD

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Summary
We studied the validity of a recently introduced, handheld, electronic loading device in providing automatically processed information on external inspiratory work, power and breathing pattern during loaded breathing tasks in patients with COPD. Thirty-five patients with moderate to severe COPD performed an endurance breathing task against a fixed resistive inspiratory load that corresponded to 55 ± 13% of their maximal inspiratory pressure. Flow and pressure signals during this task were sampled and processed at 500 Hz by the handheld loading device and at 100 Hz with an external, laboratory system that provided the "gold standard" reference data. Intra Class Correlations between methods were 0.97 for average mean inspiratory power, 0.98 for average mean pressure, 0.98 for average duty cycle, and 0.99 for total work (all $p < 0.0001$). We conclude that the handheld device provides automatically processed and valid estimates of physical units of energy during loaded breathing tasks. This enables health care providers to quantify the load on inspiratory muscles during these tests in daily clinical practice.

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Introduction

Assessment of the physical challenge undertaken by the inspiratory muscles during loaded breathing tasks has traditionally utilized the average pressure and duration of inspiratory cycles, the so called pressure time index.[1–3] However, external work and power are more representative of the magnitude of the physical task undertaken by the inspiratory muscles. Measuring these physical quantities usually requires labor intensive processing of continuous pressure, flow, and volume signals obtained by external, laboratory measurement equipment.[4,5] We studied the validity of a recently introduced, handheld, electronic loading device in providing automatically processed information on external inspiratory work, power and breathing pattern during loaded breathing tasks in patients with COPD.

Methods

Thirty-five patients with moderate to severe COPD performed an endurance breathing task against a fixed resistive inspiratory load corresponding with 55 ± 13% of their maximal inspiratory pressure (PowerBreathe KH1, HaB International Ltd, UK). More information on general characteristics of patients is provided in the online data supplement Table S1. Patients were seated, wore a nose-clip and received standardized instructions and encouragement to facilitate maximal performance during the test. They were instructed to continue breathing until task failure. Subjects could choose their own breathing frequency but were instructed to perform forceful and deep inspirations followed by complete expirations. Complete expiration was indicated by an acoustic signal provided by the handheld loading device upon cessation of flow at the completion of expiration. Flow and pressure signals were sampled and processed at 500 Hz by the handheld loading device (POWERbreathe KH1, HaB International Ltd, UK), and at 100 Hz with a Jaeger Masterlab pneumotachograph (Erich Jaeger GmbH, Würzburg, Germany), interfaced externally. Volume calibration of the external, laboratory system was performed prior to the test against the selected resistance for the endurance task to ensure valid flow and volume measurements. Signals from the pneumotachograph were captured by PC using J-Lab software version 5.22.1.50 (Cardinal Health GmbH, Hoechberg, Germany) and then processed using a statistical software package (SAS 9.3, SAS Institute Inc., Cary, NC, USA).

Table 1 Comparison of average values as assessed by the two methods.

	Laboratory ($n = 35$)	Handheld ($n = 35$)	p-Value
Avg. mean inspiratory pressure, cmH_2O	18.5 ± 6.3	19.3 ± 6.8	0.61
Avg. T_i/T_{tot} (duty cycle), %	29.1 ± 9.4	27.4 ± 9.4	0.48
Avg. mean power per breath, Watt	2.23 ± 1.21	2.25 ± 1.26	0.93
Total external inspiratory work, J	189 ± 190	169 ± 167	0.65

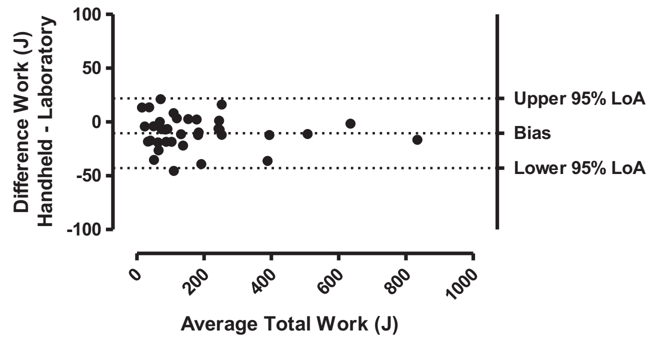

Figure 1 Agreement between estimates of total external work performed by the inspiratory muscles during the loaded breathing task as assessed by the two methods. LoA = Limit of Agreement.

External inspiratory work was calculated by integrating products of pressure and volume over all inspiratory cycles. Average mean Inspiratory power was calculated by integrating products of pressure and flow over all inspiratory cycles. The external, laboratory system provided the "gold standard" reference data. Data from the handheld device were processed internally in real time and were immediately available for readout upon completion of the test. Test averages of duty cycle (T_i/T_{tot}), mean inspiratory pressure, and mean inspiratory power were provided along with a calculation of total external inspiratory work. Intra Class Correlations and Bland Altman plots were used to determine the agreement between the two measurement methods. Average values of the external, laboratory equipment and the handheld device were compared with paired t-tests. Statistical analyses were performed with SPSS software (version 19.0; SPSS Inc, Chicago, IL).

Results

Characteristics of the endurance breathing task as assessed by the external, laboratory system are presented in Table S2 in the online data supplement. Comparisons of average values (mean ± SD) as obtained by the two measurement methods are presented in Table 1.

Intra Class Correlations between methods were 0.97 for average mean inspiratory power, 0.98 for average mean pressure, 0.98 for average duty cycle, and 0.99 for total work (all $p < 0.0001$). Agreement between methods is presented in Fig. 1 for total work (average bias: −10 J; 95%LoA: −43 to 22 J) and in Fig. S1–3 in the online data supplement for average mean inspiratory power (average bias: 0.07 W; 95% LoA: −0.61 to 0.76 W), average mean pressure (average bias: 0.78 cmH_2O; 95%LoA: −1.79 to 3.35 cmH_2O) and average duty cycle (average bias: −1.64%; 95%LoA: −5.62 to 2.34%).

Conclusions

Strong agreement was found between measurements of the handheld loading device and data obtained by the external, laboratory measurement equipment. The handheld device provides automatically processed and valid estimates of physical units of energy which are essential to quantify the load on inspiratory muscles during resistive breathing tasks.

This enables health care providers to quantify the load on inspiratory muscles during these tests in daily clinical practice.

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All patients provided written informed consent to participate in the study. The study was approved by the Ethics Committee of the University Hospital Gasthuisberg.

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Appendix A. Supplementary data

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.rmed.2013.01.020.

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Conflict of interest statement

None declared.

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